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Critical travel time impact factors at the implementation of the Athens Great Walk

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Abstract

The aim of this paper is the investigation of the critical factors affecting travel time in Athens, Greece, during the pilot implementation of the Athens Great Walk, a series of novel traffic and parking interventions for the city center. Travel time data collected in 12 routes using Google Maps API which were combined with traffic and pedestrians volumes and road geometry characteristics. Five linear and lognormal regression models were developed to determine the factors that affect the travel time on five road types. The results revealed that the factors affecting travel time are significantly related to the motorized traffic, active transport modes as well as road geometry characteristics. The passenger car share affects negatively the travel time in four of the five road types. The bus share and pedestrian traffic are significantly affect the travel time in three road types.

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Keywords: travel time; road sections; traffic; geometric chracteristics; linear regression; lognormal regression

1. Introduction

Urban centers face problems caused by road transport considering increasing levels of congestion, delays, parking difficulties, road accidents, high levels of road noise and environmental impacts. Among the various concepts that have appeared in recent decades, one of the most important is Sustainable Mobility (Banister, 2008). This idea envisions an urban environment that meets modern needs of road users promoting Public Transport, walking and cycling, introducing innovative modes of transport (e.g. micromobility and shared modes of transport), controlling the use and ownership of private cars (Bakogiannis et al., 2019; Nikitas, 2018).

Regarding the city center of Athens and its wider urban complex, the traffic congestion level appears quite high while the level of service of commuters is not equivalent to that of other similar European cities. Often, high travel times, travel delays and significant environmental burden are observed. In particular, according to TomTom, 2022 on

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average, travel times in Athens were 43% longer than during the baseline non-congested conditions in 2019, 34% in 2020 mainly due to the pandemic COVID-19 and the traffic restrictions while there was an increase to 37% in the year 2021. Also, Athens is the 18th in the ranking of European cities, with the highest levels of traffic congestion. Traffic in Athens is deteriorating and traffic congestion is expected to further increase if no immediate action is taken.

The continuous increase of the Athenian vehicle fleet in combination with the decrease of the new registrations from 2007 onwards (ELSTAT), indicates that old technology cars are not withdrawn which leads to an aging vehicle fleet. The large share (69%) of motor vehicles traveling in the Athens city center (ELSTAT), combined with the high average age of the vehicle fleet is a major cause of atmospheric and noise pollution.

Since Autumn of 2019, a series of novel traffic and parking interventions for the center of Athens were examined, part of the new mobility policy of the City of Athens, and harmonized both with the Athens Sustainable Urban Mobility Plan and the related trends in European cities. The new mobility interventions formed a major urban regeneration plan called the Athens Great Walk (AGW). The objective of the new mobility interventions is to create a new quality in urban mobility, promote public transport and active travel modes, in order to achieve safe, green and efficient transport for all.

In June 2020 a pilot implementation of a subset of the new mobility interventions was decided, following the example of several cities worldwide on the occasion of the pandemic, to support active travel modes, to assess the mobility interventions in practice, to initiate a live public consultation and dialogue based on pilot results and to guide travelers towards better mobility behaviour. More specifically, the subset of interventions implemented were the increase of sidewalks in streets with high pedestrian traffic, exclusive lanes for pedestrians and cyclists, exclusive bus lanes and motorcycle, taxi and disabled parking management.

In that context, the aim of this paper is the identification of the critical factors affecting travel time in Athens, the capital of Greece, during the pilot implementation of the AGW, a series of novel traffic and parking interventions for the city center. For this purpose, travel time data collected in 12 central routes using Google Maps API for a time period of 5 months, June - October 2020. Then, travel time data were combined with vehicles and pedestrians volume collected through field measurements and road geometry characteristics of the road sections under consideration. Five linear and lognormal regression models were developed to determine the factors that affect the travel time in the city center of Athens, as presented in the following chapters.

2. Background

Urban centers increasingly face problems caused by road transport. Many cities around the world have implemented policies to promote sustainable urban mobility. In urban areas with limited car access and car share, pedestrians and cyclists enjoy a cleaner, quieter and safer environment. These cases illustrate the possibilities for more efficient and sustainable use of the urban road network, as an "interactive and exchange space" than simple "traffic space", recognizing the social importance of roads.

It is observed that in the cities that were implemented sustainable traffic interventions related to sidewalks, replanning of public spaces and development of new or improved cycling infrastructure, the results were positive both in environmental and mobility terms. Urban sustainable mobility seems to create a new ethos in transportation sector (Nikitas et al., 2019) enhancing social justice, economic efficiency, environmental protection (Gudmundsson, 2004) and contributing positively to urban centers and in their built environments (Attard & Shiftan, 2015). The establishment of a sustainable mobility culture in cities is a difficult task that requires the adoption and implementation of an integrated and multimodal approach to urban planning and transport (Sdoukopoulos et al., 2019; Bakogiannis et al., 2016). Sustainable mobility promotes multimodality and therefore promotes the limitation of the existing dominance of private cars in urban road networks (Carroll and Yamamoto, 2015, McAndrews et al., 2017).

Nowadays, traffic congestion is one of the main problems facing cities and, unfortunately, it is expected to deteriorate in the future. This phenomenon is endemic because of the increasing unsustainable urbanization affecting negatively the quality of life and the productivity of residents and tourists of an urban center. At the same time, vehicle ownership is increasing with unprecedented rates, even faster than population and income levels (Dargay et al., 2007, Gwilliam, 2003).

Travel time analysis and the investigation of the parameters that affect travel time contributes to the promotion of sustainable mobility and helps to evaluate the new and current mobility interventions in an urban center. Travel time is one of several indicators to quantify congestion level (Erdelić et al., 2021; Tang et al., 2016). However, based on World Bank, 2010 commute travel time partially reflects congestion and delays, since a higher travel time may be due to others causes such as different spatial structure, with longer commute distances (Gillis et al.,2015). The European Commission has developed a set of sustainable urban mobility indicators (SUMI) taking into account, as one of them, the duration of commute to and from work or an educational establishment using any types of modes. So travel time analysis is required for the planning, design and evaluation of mobility interventions considering the actual need of sustainability in urban centers.

3. Data Collection

3.1. Travel time

For the purpose of this paper, travel time data collected using Google Maps Application Programming Interface (API). In order to estimate the travel time using the Google Maps API, location information in the form of geographic coordinates is fed to Google Maps for geocoding. In each iteration, the travel time is estimated between a point of origin and a point of destination by calling the Google Directions API.

More specifically, sixteen (16) routes were defined on central, entry, exit and ring road axes in the nearby area of the influence of the parking and traffic interventions of the Athens Great Walk. For each examined route the average travel time per 10 minutes on the working days (M-F) from 15 June to 23 October, 2020 was collected. The travel time data collected during the morning 08:00-10:00 and the afternoon 14:00-15:00 peak period. The category of drivers includes drivers of all travel mode without any specific distinction.

3.2. Traffic Volumes

The collection of modal split data was carried out conducting field measurements through observations by transport engineers. Thursday was chosen as the typical day for the measurements. The traffic volumes per transport mode were recorded for 30 minutes for the periods 08:00-10:30 (morning peak) and 14:00-15:00 (afternoon peak) and for the first 14 weeks of the pilot operation of the AGW. Specifically, the traffic volumes of the following transport modes were counted: private passenger cars, taxis, trucks, buses, motorcycles, bicycles, mopeds, pedestrians. The field survey for the modal split estimation in the center of Athens was carried out on 12 of the 16 routes under consideration for the travel time data collection. The following table presents the examined routes in the center of Athens.

Table 1. The examined routes

	Routes	Origins	Destinations	Length	Field Survey Point
	Central Road Axis				
1	Panepistimiou (Vas. Sofias- Patision)	37.976436, 23.735838	37.983900, 23.729416	1,025 m	Sina & R. Feraiou
2	Akadimias (Patision - Vas.Sofias)	37.985922, 23.729946	37.976065, 23.737587	1,339 m	Sina & R. Feraiou
3	Solonos (Vas. Sofias - Patision)	37.975853, 23.739066	37.986440, 23.730039	1,511 m	Sina & Asklipiou
4	Stadiou (Aiolou - Vas. Georgiou)	37.982926, 23.729152	37.976232, 23.734337	882 m	Kolokotroni & Christou Lada
	Entry Road Axis				
5	Vas. Sofias (Vas. Konstantinou - Panepistimiou)	37.976369, 23.749300	37.976154, 23.735860	1,214 m	Sekeri & Akadimias
6	Vas. Sofias (Kifisias - Vas. Konstantinou)	37.986385, 23.761158	37.976375, 23.749409	1,528 m	
7	Vas. Amalias (Ath. Diakou - Panepistimiou)	37.968445, 23.731712	37.976063, 23.735778	969 m	Xenofontos & Othonos
8	Patision (Alexandras - Stadiou)	37.991676, 23.731214	37.983005, 23.729134	980 m	-
	Exit Road Axis				
9	Vas. Sofias (Panepistimiou-Vas. Konstantinou)	37.976102, 23.736190	37.976275, 23.749160	1,170 m	Sekeri & Akadimias
10	Vas. Sofias (Vas. Konstantinou- Kifisias)	37.976296, 23.749535	37.986332, 23.761284	1,530 m	
11	Vas Amalias (Filellinon- Ath. Diakou)	37.972001, 23.733795	37.968438, 23.731616	476 m	-
12	Filellinon (Vas. Georgiou-Vas. Amalias)	37.976149, 23.734280	37.972055, 23.733766	488 m	Kar. Servias & Mitropoloeos
	Ring Road Axis				
13	Vas.Konstantinou (Ardittou-Vas. Sofias)	37.967112, 23.733536	37.976113, 23.749256	1,733 m	Rizari & S. Merkouri
14	Vas.Konstantinou (Vas. Sofias-Ardittou)	37.976192, 23.749160	37.967245, 23.733537	1,719 m	
15	Alexandras (Kifisias-Patision)	37.986568, 23.761195	37.991810, 23.731507	2,667 m	Vournazou & K. Loukareos
16	Alexandras (Patision-Kifisias)	37.991672, 23.731488	37.986469, 23.761150	2,664 m	

The examined road axes were grouped in 4 categories according to the location and type of each road axe. The route on Panepistimiou St. from Vas. Sofias to Patision was investigated separately from the other routes due to the implementation of mobility intervention in the context of the AGW. In the first time period of pilot operation (from 06/14/2020 to 07/31/2020) of AGW, an increase of the sidewalk (9 meters additional sidewalk) and decrease of traffic lanes to 3 was implemented on Panepistimiou St. In the second period (from 03/08/2020 until today) an additional traffic lane was given to the motorized traffic and therefore the road operated with four traffic lanes.

3.3. Road Characteristics

Regarding the geometric characteristics of the examined road axes, the number of traffic lanes and the existence of bus lane were taken into account. For this purpose, using Google Street View for each modal split measurement point the number of traffic lanes and the existence or non-existence of bus lanes were found. The Athens Urban Transport Organization (OASA) was also used to confirm the existence of bus lanes observed through Google Street View.

It is also worth mentioning that for the investigation of the traffic conditions on Panepistimiou Street and in the nearby area due to the interventions of the Great Walk, a discrete variable, that concerns only the traffic lanes of Panepistimiou and it is coded with 0 during the time Panepistimiou had three traffic lanes (14/06/2020 - 31/07/2020), while with 1 in the period that Panepistimiou had four traffic lanes (from 03/08/2020), has been used. The variables related to the bus lanes and the peak period are also coded. For non-bus lane the variable is coded with 0, while for the existence of a bus lane it is coded with 1.

4. Results

4.1 Descriptive Analysis

A preliminary part of the analysis focused on interpreting collected data using descriptive statistics.

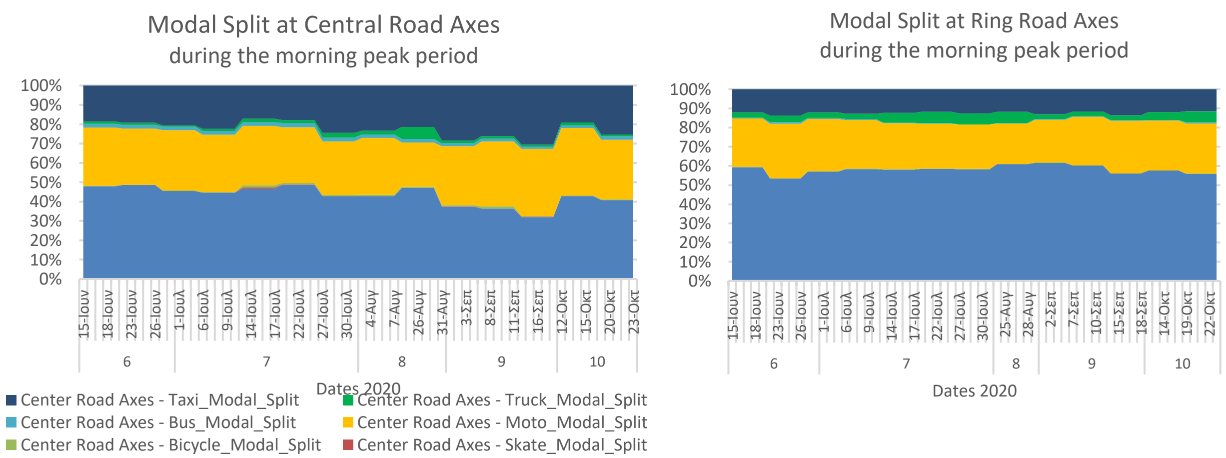

Fig. 1. Modal split at (a) central road axes (b) ring road axes during the morning peak period

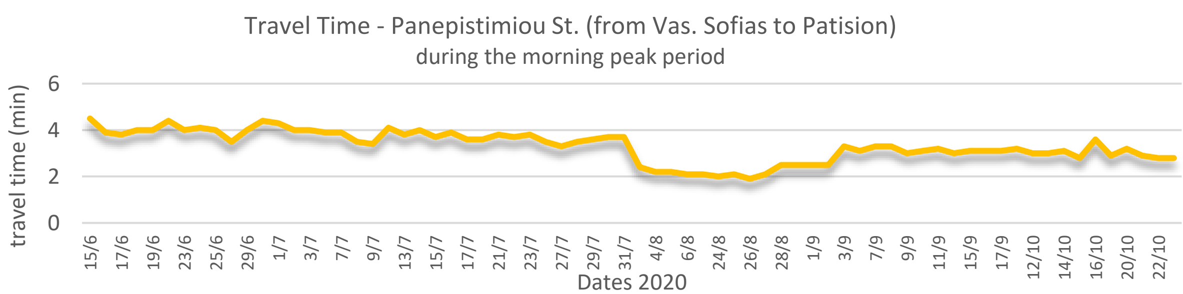

Fig. 2. Travel time on Panepistimiou St. during the morning peak.

It is observed that the largest traffic share is occupied by passenger cars, motorcycles and taxi, during the morning peak period. There is a decrease in the passenger cars share in September, while there is a simultaneous increase in use of motorcycles and taxis. On the ring road axes, no significant differentiation is observed in the modal split during the time period under consideration. Also, the use of passenger cars seems to be quite high.

Based on Fig. 2, there is a significant decrease of travel time on Panepistimiou St. during August, possibly due to the summer holidays, while there is an improvement in September. The maximum value of the travel time to Panepistimiou is 4.5 minutes and it is observed in the first week of pilot operation of traffic interventions in the context of the Athens Great Walk.

4.2 Statistical Analysis

Following the described data collection and processing, it was decided that multiple linear regression and log-normal regression models would be appropriate for the statistical analysis of travel time. Specifically, regression models were developed to model how traffic measures considering traffic volume and modal split and, road geometry characteristics influence the travel time in the city center of Athens during the pilot implementation of Athens Great Walk. In Central, Entry and Ring Road Axes log-normal regression was implemented as it provided a better overall model fit. Linear regression is a widely known, simple technique (and as such we will omit the mathematics behind it) used to model a linear relationship between a continuous dependent variable and one or more independent variables (Washington et al., 2010). Emphasis is given on presenting reliability data issues and their handling procedures. An integral part of the results are the statistical checks required for acceptance or rejection of the models. The final model results appear on the following table.

Table 2. Critical travel time impact factors during the pilot operation of the Athens Great Walk

	Panepistimiou				**Central Road Axes**				**Entry Road Axes**				**Exit Road Axes**				**Ring Road Axes**			
Variables	Travel_Time				log(Travel_Time)				log(Travel_Time)				Travel_Time				log(Travel_Time)			
	βi	t	ei	ei*	βi	t	ei	ei*	βi	t	ei	ei*	βi	t	ei	ei*	βi	t	ei	ei*
Moto_Volume	0.00	5.86	0.00	2.12	-	-		-	-	-		-	-	-		-	-	-		-
PC_ModalSplit	-2.78	-5.03	0.00	-1.97	-0.37	-5.13	0.00	-5.25	-0.48	-3.81	-0.01	-3.50	-	-		-	-0.92	-11.22	-0.01	-118.63
Bus_ModalSplit	23.54	3.05	0.00	1.00	7.23	14.50	0.00	4.07	-	-		-	-	-		-	2.66	2.22	0.00	3.10
Pedestrian_Volume	0.00	5.77	0.00	1.00	0.00	3.28	0.00	1.00	0.00	2.86	0.00	1.00	-	-		-	-	-		-
Panep_AGW_Lanes	1.11	8.62	0.31	1.00	-	-		-	-	-		-	-	-		-	-	-		-
Traffic_Lanes	-	-		-	-0.48	-36.40	-0.03	-43.19	-0.16	-8.19	-0.01	-9.08	-	-		-	-	-		-
Peak_Period	-	-		-	-0.10	-10.04	-0.21	1.00	0.12	5.92	0.30	1.00	-	-		-	0.10	7.93	0.25	1.00
Truck_Volume	-	-		-	-	-		-	-	-	-	-	0.00	2.30	0.00	2.73	0.00	-4.26	0.00	-12.88
Bus_Lanes	-	-		-	-	-		-	-	-	-	-	-3.03	-30.47	-1562	1.00	-	-		-
Bicycle_Volume	-	-		-	-	-		-	-	-	-	-	0.01	1.93	0.00	1.00	-	-		-
Moto_ModalSplit	-	-		-	-	-		-	-	-	-	-	1.25	2.16	0.00	4.70	-	-		-
Bicycle_ModalSplit	-	-		-	-	-		-	-	-	-	-	-	-		-	4.21	2.23	0.00	1.00
Taxi_ModalSplit	-	-		-	-	-		-	-	-	-	-	-	-		-	1.81	10.69	0.01	56.01
R^2	**0.633**				**0.791**				**0.307**				**0.810**				**0.458**			

To complement the developed models, elasticity analyses were conducted as well. As defined in practice, elasticity analyses allow for the quantification of the response of the dependent variable for a 1% change of an independent continuous variable. When dealing with independent categorical variables, it is meaningful to implement pseudo-elasticities to obtain the incremental changes that are incurred as a result of category changes in the categorical variables (Washington et al., 2010). By using elasticity (and pseudo-elasticity) analyses, the influence of each variable on the travel time was thus quantified.

The final models were evaluated considering the common statistical tests (R^2, t- test etc.) but also based on the logical explanation of the results. Also, the correlation of variables was examined to select the best-fitting mathematical model. The final models have an adjustment factors R^2 from 0.3 to 0.8, which are considered adequate for linear and lognormal regression models. Variables are considered statistically significant at the typical 95 % level. Based on models results the parameters that affect the travel time are presented below.

Table 3. The variables of the models

Variable	Description	Type
Moto_Volume	Hourly traffic volume of motorcycles	continuous
PC_Modal_Split	The modal share (%) of private cars	continuous
Bus_Modal_Split	The modal share (%) of buses	continuous
Pedestrian_Volume	Hourly volume of pedestrians	continuous
Panep_AGW_Lanes	Number of traffic lanes on Panepistimiou St. on the 1st and 2nd pilot operational period of AGW	0: 3 lanes (14/06-31/07/2020) 1: 4 lanes (03/08/2020-)
Traffic_Lanes	Number of traffic lanes	continuous
Peak_Period	Morning or afternoon peak period	0: morning, 1: afternoon
Truck_Volume	Hourly traffic volume of trucks	continuous
Bus_Lanes	Existence of bus lane	0: Non-existence, 1: Existence
Bicycle_Volume	Hourly traffic volume of bicycles	continuous
Moto_Modal_Split	The modal share (%) of motorcycles	continuous
Bicycle_Modal_Split	The modal share (%) of bicycles	continuous
Taxi_Modal_Split	The modal share (%) of taxis	continuous

Panepistimiou Street

The elasticity analysis for the Panepistimiou St. shows that the most important factors affecting travel time on the examined route appears to be the hourly volume of motorcycles and the modal share of passenger cars. An increase of 100 motorcycles per hour on the route from Vas. Sofias to Patision increases the travel time by 0.14 minutes, while an increase of 1% of passenger car share decreases the travel time by 2.8 minutes. This is probably because the overall traffic flow could be better in conditions with less heavy vehicles (buses, trucks), and motorcycles. Considering that motorcycles make overtaking and maneuvering, traffic delays are likely to occur.

The hourly volume of pedestrians on Panepistimiou St. is also a statistical significant parameter that affect the travel time. Specifically, an increase of the hourly walking leads to an increase of the travel time. This may be explained by the fact that pedestrians may cross the street with a red pedestrian traffic light or even walk along the road instead of on the sidewalks. The increase of the number of traffic lanes on Panepistimiou St. from three to four lanes and the reduction of pedestrian sidewalk, leaded to an increase of travel time on the examined route. Possibly, the extra lane gave space to more vehicles, combined with increased travel demand in the fall (2nd pilot period) compared to the summer (1st pilot period), resulting in higher congestion levels and higher travel times.

Central and Entry roads axes

Regarding central and entry road axes the most statistical significant parameters that affect the travel time on the examined routes are the passenger car share, the hourly walking, the number of traffic lanes, and the peak period.

Also, the analysis shows that an additional factor that affect the travel time on central road axes is the bus share. An increase of 1% of passenger car share could lead to a decrease of the logarithm of travel time on the examined group of central and entry road axes by 0.003% and 0.005%, respectively. However, an increase of 1% of bus share could lead to an increase of the logarithm of travel time on the examined central road axes by 0.003%. The elasticity analysis shows that the passenger car share is the most important continuous parameter that affect the travel time on the road axes under consideration.

An increase of the hourly pedestrian traffic leads to an increase of the travel time. Regarding the number of traffic lanes, increasing traffic lanes by ones leads to a reduction in travel time since the more road space available, the fewer traffic jams. It also appears that the travel time on the central road axes during the morning peak hours is higher than in the afternoon peak hours. This may be due to the increased commuting in the morning hours with the purpose of work. However, the analysis for the entry road axes shows that on the afternoon peak hours, there is an increase in the travel time comparing to the morning peak. This is possibly due to the fact that during the afternoon hours drivers commute to the city center of Athens for entertainment (e.g. shopping), and making frequent stops for parking.

Exit road axes

The statistical analysis for the exit road axes shows that the significant parameters for the travel time are the hourly volume of trucks, the modal share of motorcycles, the hourly volume of bicycles and the bus lanes. An increase of 100 trucks per hour, increases the travel time by 0.2 minutes. This is because the trucks, as heavy vehicles, may create a traffic problem with the immediate consequence of increasing the travel time. However, an increase of 1% of motorcycle share increases the travel time by 1.2 minutes. This may be due to the maneuvers and overtaking of the motorcycles, which affect the smooth flow of the overall traffic.

Regarding the bus lanes, the addition of them could lead to a decrease of travel time by 3 minutes. Probably, the relationship between the two sizes is explained by the fact that the buses do not use the rest of the road space as long as they move in the bus lane and thus facilitate the movement of the other vehicles. At the same time, as the traffic volume of bicycles increases, the travel time increases. This may be explained by the fact that cyclists use road space that corresponds to other vehicles and being vulnerable users cause delays in other traffic, leading, finally, to increased travel time.

Ring road axes

Regarding the ring road axes, the elasticity analysis shows that the most important factors affecting the travel time are the modal share of passenger car and the modal share of taxi. An increase of 1% of passenger car share decreases the travel time by 0,9 minutes, while an increase of 1% of taxi share increases the travel time by 1,8 minutes. This is probably because taxi make frequent stops, leading to congestion and increased travel times.

The modal share of bus is also a statistical important parameter that affect the travel time on the examined routes. An increase of 1% of bus share, could lead to an increase of travel time by 2.7 minutes. This could be logically explained by the fact that buses take up a lot of space on the road as large vehicles and cause traffic delays, increasing the travel time of vehicles. Also, an increase of 1% of bicycle share increases the travel time by 4.2 minutes. Cyclists, as vulnerable users, can contribute to delays and thus increase travel time.

Regarding the peak period, during the transition from morning to afternoon peak, the travel time increases. This may be justified by the fact that the afternoon peak period coincides with the return from work. At the same time, in the afternoon, the regional roads may be used for entertainment.

5. Discussion

The aim of this paper is the identification of the critical factors affecting travel time in Athens, the capital of Greece, during the pilot implementation of the Athens Great Walk, a series of novel traffic and parking interventions for the city center. For this purpose, travel time data collected in 12 central routes using Google Maps API which then were combined with vehicles and pedestrians volume collected through field measurements and road geometry characteristics of the road sections under consideration. The examined time period was 5 months, June - October 2020.

Five linear and lognormal regression models were developed to determine the factors that affect the travel time in the city center of Athens. The results revealed that in the context of the pilot implementation of AGW mobility interventions, on Panepistimiou St., the increase of the traffic lanes from three (Phase A) to four (Phase B) which carried out led to a travel time increase. This may be due to the fact that the extra traffic lane attracted additional vehicles and illegally parked cars, combined with increased travel demand in autumn (Phase B) comparing to summer (Phase A), resulting in higher traffic congestion and longer travel times.

Also, the results revealed that the factors affecting travel time are significantly related to the motorized traffic, active transport modes as well as road geometry characteristics. The increase of passenger cars share affects negatively the travel time in four of the five statistical models. The bus share, pedestrian traffic and peak period are significantly affect the travel time in three models. In two or fewer models, the parameters that determine the travel time are the traffic volume of motorcycles, the change of the number of traffic lanes on Panepistimiou St. during the pilot operation of AGW, the number of traffic lanes per examined road section, the traffic volume of trucks and bicycles, the existence of bus lane, the taxis, motorcycles and bicycles shares.

The central road axes and the entrance road axes have similar behavior regarding the factors that affect travel time. These two models have the same independent variables with the only difference being that the model of central road axes has an additional variable, the bus share. The increase of passenger car share leads to a reduction in travel time to all examined types of road axes except exit roads, where it is not significant. Probably, this is because the overall traffic flow is better in conditions with fewer heavy vehicles (buses, trucks) and taxis and motorcycles.

Regarding active transport modes, pedestrian traffic arises statistically important only on Panepistimiou St., on the center roads and on the entrance roads, while its influence on all the above-mentioned axes lead to an increase in the travel time of vehicles, possibly due to the fact that pedestrians may be crossing the road with a red traffic light for pedestrians delaying the rest of the traffic. Bicycles affect exit and ring roads and their influence leads to an increase in travel time. This may be due to the fact that cyclists use road space and being vulnerable users cause delays in other traffic.

Regarding the peak period, it is observed that on the center roads axes, the travel time is increased during the morning peak compared to the afternoon while on the entrance roads and the ring roads the opposite happens. Concerning the central road axes, this may be explained by the morning movement of the drivers to their work. As far as the entrance and the ring roads, the increased travel time may be due to the transportation for the purpose of shopping and leisure but also on the way back from the work.

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